

The invention claimed is:

1. A high temperature, molten electrolyte electrochemical cell comprising:  
ash-free, turbostratic carbon particles having a maximum diameter of less than one micrometer.
2. The electrochemical cell in claim 1, wherein said electrochemical cell is a battery.
3. The electrochemical cell in claim 1, wherein said electrochemical cell is a fuel cell.
4. The electrochemical cell in claim 1, wherein said carbon particles have an x-ray diffraction d (002) line that is greater than about 0.34 nanometers.
5. The electrochemical cell in claim 1, wherein said carbon particles are selected from the group consisting of pyrolysis products of substantially pure hydrocarbons, pyrolysis products substantially pure petroleum coke and pyrolysis products of substantially pure petroleum oil or petroleum distillates or petroleum cracking products.
6. The electrochemical cell in claim 5, wherein the substantially pure hydrocarbon contains an alkyne.
7. The electrochemical cell in claim 5, wherein the substantially pure hydrocarbon contains is acetylene.

8. The electrochemical cell in claim 1, wherein said carbon particles are entrained in said molten electrolyte.

9. A high temperature, molten electrolyte electrochemical cell for directly converting a carbon fuel to electrical energy, the electrochemical cell comprising:

a cathode compartment having an oxygen-containing gas and a molten electrolyte;

an anode compartment having a slurry comprising said molten electrolyte and carbon particles entrained in said molten electrolyte; and

an electron insulating, ion conducting, porous ceramic separator between said cathode compartment and said anode compartment.

10. The electrochemical cell in claim 9, wherein said electrochemical cell is a battery.

11. The electrochemical cell in claim 9, wherein said electrochemical cell is a fuel cell.

12. The electrochemical cell in claim 9, wherein the oxygen-containing gas consists essentially of elemental, diatomic oxygen.

13. The electrochemical cell in claim 9, wherein the oxygen-containing gas comprises air.

14. The electrochemical cell in claim 9, wherein the molten electrolyte comprises metal carbonates.

15. The electrochemical cell in claim 9, wherein the molten electrolyte comprises a mixture of one or more components selected from the group consisting of  $\text{Li}_2\text{CO}_3$ ,  $\text{K}_2\text{CO}_3$ , and  $\text{Na}_2\text{CO}_3$ .

16. The electrochemical cell in claim 9, wherein the molten electrolyte comprises the mole ratio of 38%  $\text{Li}_2\text{CO}_3$  / 62%  $\text{K}_2\text{CO}_3$ .

17. The electrochemical cell in claim 9, wherein said carbon particles have an x-ray diffraction d(002) line that is greater than about 0.34 nanometers.

18. The electrochemical cell in claim 9, wherein said carbon particles are selected from the group consisting of pyrolysis products of substantially pure hydrocarbons, pyrolysis products substantially pure petroleum coke and pyrolysis products of substantially pure petroleum oil or distillates.

19. The electrochemical cell in claim 18, wherein the substantially pure hydrocarbon contains an alkyne.

20. The electrochemical cell in claim 18, wherein the substantially pure hydrocarbon contains is acetylene.

21. The electrochemical cell in claim 9, wherein the porous ceramic separator is saturated with the molten electrolyte.

22. The electrochemical cell in claim 9, wherein the porous ceramic separator is a non-reactive metal oxide selected from the group consisting of  $\text{ZrO}_2$ ,  $\text{MgO}$ ,  $\text{LiAlO}_2$ ,  $\text{CaO}$ ,  $\text{Al}_2\text{O}_3$ , rare earth oxides, and combinations thereof.

23. The electrochemical cell in claim 21, wherein the non-reactive metal oxide is constructed in the form of a cloth, felt, fabric, porous planar plate, or porous tubular plate.

24. The electrochemical cell in claim 9, wherein the porous ceramic separator is less than 2 mm thick and is impermeable to bubbles when wetted.

25. A high temperature, molten electrolyte electrochemical cell for directly converting a carbon fuel to electrical energy, the electrochemical cell comprising:  
a cathode compartment formed by a housing comprising non-porous, inert material having a gas inlet and a gas outlet, an oxygen-containing gas, a molten electrolyte, and a cathode current collector;  
an anode compartment having an inlet, an anode current collector, and a slurry comprising said molten electrolyte and a plurality of carbon particles entrained in said molten electrolyte; and

an electron insulating, ion conducting, porous ceramic separator between said cathode compartment and said anode compartment, said porous ceramic separator capable of allowing transport of ions produced in said cathode compartment to said slurry.

26. The electrochemical cell in claim 25, wherein said electrochemical cell is a battery.

26. The electrochemical cell in claim 25, wherein said electrochemical cell is a fuel cell.

28. The electrochemical cell in claim 25, wherein the non-porous, inert material contains one or more materials selected from the group consisting of stainless steel, stainless steel coated with a non-reactive ceramic material, stainless steel coated with a non-reactive metal oxide film, metal, ceramic.

29. The electrochemical cell in claim 25, wherein the oxygen-containing gas consists essentially of elemental, diatomic oxygen.

30. The electrochemical cell in claim 25, wherein the oxygen-containing gas comprises air.

31. The electrochemical cell in claim 25, wherein the molten electrolyte comprises a carbonate.

32. The electrochemical cell in claim 25, wherein the molten electrolyte comprises one or more components selected from the group consisting of  $\text{Li}_2\text{CO}_3$ ,  $\text{K}_2\text{CO}_3$ , and  $\text{Na}_2\text{CO}_3$ .

33. The electrochemical cell in claim 25, wherein the molten electrolyte comprises the mole ratio of 38%  $\text{Li}_2\text{CO}_3$  / 62%  $\text{K}_2\text{CO}_3$ .

34. The electrochemical cell in claim 25, wherein the cathode current collector is a metal selected from the group consisting of Ni, Au, Ag, Pt, Pd, Cu, Co, alloys thereof, and Fe alloys thereof.

35. The electrochemical cell in claim 25, wherein the cathode current collector comprises stainless steel.

36. The electrochemical cell in claim 25, wherein said cathode current collector is a grid, felt, screen, foam, mesh or sintered frit.

37. The electrochemical cell in claim 25, wherein the cathode current collector is positioned such that it is in contact with the oxygen-containing gas and is at least partially in contact with the molten electrolyte.

38. The electrochemical cell in claim 25, wherein the cathode current collector is positioned such that it is in contact with the oxygen-containing gas and is in contact with the molten electrolyte, but less than fully saturated.

39. The electrochemical cell in claim 25, wherein the anode current collector comprises a porous metal structure that will not melt at the operating temperature of the cell.

40. The electrochemical cell in claim 39, wherein the porous metal structure comprises a grid, felt, screen, foam, mesh, sponge or sintered frit.

41. The electrochemical cell in claim 25, wherein the anode current collector comprises a porous metalloid structure that will not melt at the operating temperature of the cell.

42. The electrochemical cell in claim 41, wherein the porous metalloid structure comprises a grid, felt, screen, foam, mesh, sponge or sintered frit.

43. The electrochemical cell in claim 25, wherein the ratio of the surface area of the anode current collector to the volume of the slurry is less than 1 cm.

44. The electrochemical cell in claim 25, wherein said carbon particles have an x-ray diffraction d(002) line that is greater than about 0.34 nanometers.

45. The electrochemical cell in claim 25, wherein said carbon particles have a maximum diameter of less than about one micrometer.

46. The electrochemical cell in claim 25, wherein said carbon particles are selected from the group consisting a pyrolysis product of a substantially pure hydrocarbon, a pyrolysis product of a substantially pure petroleum coke, and a pyrolysis product of a substantially pure petroleum oil or distillate.

47. The electrochemical cell in claim 25, wherein the substantially pure hydrocarbon contains an alkyne.

48. The electrochemical cell in claim 25, wherein the substantially pure hydrocarbon contains is acetylene.

49. The electrochemical cell in claim 25, wherein the porous ceramic separator comprises a non-reactive metal oxide that is saturated with the molten electrolyte.

50. The electrochemical cell in claim 49, wherein the non-reactive metal oxide is selected from the group consisting of  $\text{ZrO}_2$ ,  $\text{MgO}$ ,  $\text{LiAlO}_2$ ,  $\text{CaO}$ ,  $\text{Al}_2\text{O}_3$ , rare earth oxides, and combinations thereof.



**51.** The electrochemical cell in claim 49, wherein the non-reactive metal oxide is a cloth, felt, fabric, porous planar plate, or porous tubular plate.

**52.** The electrochemical cell in claim 25, wherein the porous ceramic separator is less than about 2 mm thick and is impermeable to bubbles when wetted.

**53.** A method for producing electrical energy comprising the steps of:

heating an electrochemical cell containing a carbon fuel entrained in an electrolyte to an operating temperature causing the electrolyte to become molten, said electrolyte containing at least one carbonate;

producing carbonate ions by bringing an oxygen-containing gas in contact with a cathode current collector wetted with the molten electrolyte;

transporting said carbonate ions through a porous ceramic separator to an anode current collector causing said carbonate ions to react with said carbon fuel; and

collecting said electrical energy produced through said anode current collector.

**54.** The method in claim 53, further comprising the step of:

entraining a carbon fuel in an electrolyte.

**55.** The method in claim 53, further comprising the step of:

pyrolyzing a source of carbon fuel wherein said source is selected from the group consisting of substantially pure petroleum coke, substantially pure petroleum oils or distillates, and substantially pure hydrocarbons.

**56.** The method in claim 53, wherein the substantially pure hydrocarbon contains an alkyne.

**57.** The electrochemical cell in claim 53, wherein the substantially pure hydrocarbon contains is acetylene.

**58.** The method in claim 53, wherein said electrochemical cell is operated as a battery.

**59.** The method in claim 53, wherein said electrochemical cell is operated as a fuel cell.

**60.** The method in claim 53, wherein said carbon particles are selected from the group consisting of a pyrolysis product of a substantially pure hydrocarbon, substantially pure petroleum coke, and substantially petroleum pure oil, petroleum cracking products or petroleum distillates.

**61.** The method in claim 53, wherein the substantially pure hydrocarbon is acetylene.

**62.** The method in claim 53, wherein said carbon particles have an x-ray diffraction d(002) line that is greater than about 0.34 nanometers.

63. The method in claim 53, wherein the molten electrolyte comprises a mixture of one or more components selected from the group consisting of  $\text{Li}_2\text{CO}_3$ ,  $\text{K}_2\text{CO}_3$ , and  $\text{Na}_2\text{CO}_3$ .

64. The method in claim 53, wherein the molten electrolyte comprises the mole ratio of 38%  $\text{Li}_2\text{CO}_3$  / 62%  $\text{K}_2\text{CO}_3$ .

65. The method in claim 53, wherein the operating temperature is between about 500 degrees C and about 900 degrees C.

66. The method in claim 53, wherein the oxygen-containing gas consists essentially of elemental, diatomic oxygen.

67. The method in claim 53, wherein the oxygen-containing gas comprises air.

68. The method in claim 53, wherein the cathode current collector is a porous metal selected from the group consisting of Ni, Au, Ag, Pt, Pd, Cu, Co, alloys thereof, and Fe alloys thereof.

69. The method in claim 53, wherein the cathode current collector comprises stainless steel.

70. The method in claim 53, wherein the cathode current collector is positioned in contact with the oxygen-containing gas and is at least partially in contact with the molten electrolyte.

71. The method in claim 53, wherein the cathode current collector is positioned in contact with the oxygen-containing gas and is at least partially in contact with the molten electrolyte, but less than saturated.

72. The method in claim 53, wherein the porous ceramic separator comprises a non-reactive metal oxide that is saturated with the molten electrolyte.

73. The method in claim 72, wherein the non-reactive metal oxide is selected from the group consisting of  $ZrO_2$ ,  $MgO$ ,  $LiAlO_2$ ,  $CaO$ ,  $Al_2O_3$ , rare earth oxides, and combinations thereof.

74. The method in claim 72, wherein the non-reactive metal oxide comprises a cloth, felt, fabric, planar plate, or tubular plate.

75. The method in claim 53, wherein the porous ceramic separator is less than about 5 nm thick and impermeable to bubbles when wetted.

76. The method in claim 53, wherein the porous ceramic separator is both electron insulating and ion conducting.

77. The method in claim 53, wherein the anode current collector is a porous metal structure that will not melt at the operating temperature of the cell.

78. The method in claim 77, wherein the porous metal structure comprises a grid, felt, screen, foam, sponge or sintered frit.

79. The method in claim 53, wherein the anode current collector is a porous metalloid structure that will not melt at the operating temperature of the cell.

80. The method in claim 79, wherein the porous metalloid structure comprises a grid, felt, screen, foam, sponge or sintered frit.

81. The method in claim 53, wherein the ratio of anodic surface area to the volume of the slurry is less than about 1 cm.

82. The method in claim 53, further comprising the step of:  
connecting two or more electrochemical cells together to operate in series.

83. The method in claim 53, further comprising the step of:  
connecting two or more electrochemical cells together to operate in parallel.

84. The method in claim 53, further comprising the step of :  
connecting the electrochemical cell to a load.